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INHERITANCE OF THE WHITE-CHEEK CHARACTER IN MICE OF THE GENUS *PEROMYSCUS*

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INTRODUCTION

IN beach mice of the races *Peromyscus polionotus leucocephalus* and *P. p. albifrons* pigmented hairs are restricted to the dorsal body surface. The hairs of the ventral and lateral surfaces are white throughout. In some mice of these races, the area of unpigmented hairs extends somewhat on the dorsal surface. Mice of the race *leucocephalus* have the least extensive area of dorsal, pigmented hairs. These mice have fully pigmented hairs only along the middorsal line. The hairs bordering the middorsal stripe are pigmented only at the base. All other body hairs are pure white. This coat pattern may be called the *leucocephalus* type.

The coat pattern of the *leucocephalus* and *albifrons* mice contrasts strongly with the pigmentation pattern of mice of the race *P. p. polionotus* and of all members of the related species *maniculatus*. The species *polionotus* and *maniculatus* are both members of the *maniculatus* species group. In the coat pattern usual for the mice of the *maniculatus* group, the hairs of the dorsal surface are pigmented throughout; and the ventral and lateral hairs, except a few in the inguinal region and on the chin, are pigmented at the base and only the tips are white. This pattern of pigmentation may be called the *maniculatus* type.

An analysis of the genetic differences between the *leucocephalus* and *maniculatus* patterns of pigmentation was made by Sumner (1930). He showed that the *leucocephalus* pattern is partly dominant over the *manicu-*

latus type and that the total difference between the two types is due to the effects of several genes. Sumner, however, did not isolate any of these factors. The present report deals with the mode of inheritance of one of these pattern genes.

It is especially desirable to analyze the genetic differences between the two types of coat pattern of these mice, because these patterns of pigmentation are adaptive in nature. The race *leucocephalus* lives on Santa Rosa Island, which is a white sand reef. The mice of this race are to our eyes relatively inconspicuous on the white sand, because their lateral surfaces and part of their dorsal surface is white. A mouse with the *maniculatus* pattern of pigmentation would on the contrary be easily seen on the white sand. Mice of the race *albifrons,* which are more extensively pigmented above than are those of *leucocephalus,* are likewise well adapted for concealment on the somewhat darker mainland beaches on which they live. Mice of the race *polionotus,* which have the *maniculatus* pattern, are inconspicuous on the dark soils that they inhabit in the interior of Georgia and Alabama. On the other hand, a mouse with the *leucocephalus* pattern would be highly conspicuous on these dark soils.

The chi-square test has been used to determine the significance of deviations from the expected ratios in the F_2 and backcross generations. With one degree of freedom a deviation is considered significant if the chi-square value exceeds 3.841, which marks the 5 per cent level of probability. A deviation is considered highly significant if the chi-square exceeds 6.635, which marks the 1 per cent level of probability.

I am indebted to Don Hayne for permission to examine several stocks of *Peromyscus polionotus* that he collected in western Florida. I am indebted to Elizabeth Barto for suggestions concerning the test for linkage with another set of factors and for critically reading the manuscript.

THE WHITE-CHEEK CHARACTER

The F_1 Generation

Cross matings first were made between mice of the *maniculatus* type, as represented by a stock of *Peromyscus maniculatus bairdii* from southwestern Michigan, and a strain of the *leucocephalus* type that had been selected for minimum extent of pigmented hairs. This *leucocephalus* strain was obtained by selection following a cross of *leucocephalus* from Santa Rosa Island with *albifrons* from the mainland of Florida. Crosses were later made between *Peromyscus maniculatus blandus* from New Mexico and *leucocephalus* from Santa Rosa Island.

The F_1 hybrids that were obtained from these crosses varied considerably in the distribution of pigmented hairs, but all of the sixty-three animals had one conspicuous character in common. The fur hairs on the cheeks up to the lower rim of the eyes were white in at least their distal band (Pl. I). In some individuals, moreover, the fur hairs in this region were white throughout their length. At least some of the guard hairs in this region, however, were dark at their tips. The white-cheek effect obtained results from the extension of the white pigmentation pattern that is characteristic of the ventral surfaces of the head and body upward toward the dorsal head surface. This character I propose to call white cheek (*Wc*) in contradistinction to the usual "colored cheek" (*wc*) of mice that have the *maniculatus* pattern of pigmentation. In the colored-cheek mice the lower rim of the eye is bordered by hairs that are pigmented to their tips.

On the hypothesis that the white cheek represents the effect of a major pattern gene that is inherited as a simple dominant over the colored cheek, the hybrids were backcrossed to colored-cheek mice, and an F_2 generation also was raised.

The F_2 Generation

Thirty-one F_2 hybrids of the cross between *bairdii* and the selected *leucocephalus*-type strain were raised. As only three F_1 males were produced in this cross, and as two of these proved sterile, all of the F_2 hybrids were the offspring of a single pair of mice. Twenty-one white-cheeked and ten colored-cheeked mice were obtained in the F_2 generation. The deviation from the expected 3 : 1 ratio is not significant, for the chi-square value is only 0.871, with one degree of freedom. The segregation in this generation agrees with the hypothesis that white cheek is a single unit dominant over colored cheek.

The Backcross to Colored Cheek

The most convincing proof that white cheek is a single unit dominant over colored cheek is found in the segregation in the backcross generation, for a much larger number of individuals was produced in this cross than in the F_2. The backcross to *bairdii* of the F_1 *bairdii* × *leucocephalus*-type strain produced fifty-eight offspring. The backcross of the F_1 *blandus* × *leucocephalus* hybrids to *blandus* has produced thirty-one offspring. In a testcross to colored-cheeked mice designed to test for linkage between white cheek and the buff phase the progeny totaled 203 individuals. The white-cheek animals used in the testcross were obtained from a second generation of backcrosses to colored-cheek mice. Among the 292 backcross animals in these three groups, 159 were phenotypically white cheek, and 133 were colored cheek. The deviation from the expected 1 : 1 ratio is not significant, for the chi-square value is only 2.315, with one degree of freedom. Therefore, the segregation in both the F_2 and backcross generations indicates that white cheek is a single unit dominant over colored cheek.

TEST FOR LINKAGE WITH BUFF–GRAY

A test was made for linkage between the white-cheek or colored-cheek alleles (*Wc*, *wc*) and the buff-gray factors (A^b, a). This test was made in the coupling relationship. Buff, white-cheeked mice, some or all of them heterozygous for colored cheek, were mated to gray, colored-cheeked mice. Buff, white-cheeked animals ($A^b\ Wc/a\ wc$) obtained from this cross were used in testcross matings, where they were mated to the double recessive, gray, colored-cheek *blandus*. The offspring of the testcross were classified at an age of four to five months.

Buff (A^b) and gray (a) have been shown by Dice (1933) to be alleles, of which buff is dominant. This later was confirmed by Clark (1938). The symbols are those used by Clark, although it has not been proved that buff belongs in the agouti series. The buff used here came from the *bairdii* used in the crosses between *bairdii* and the selected *leucocephalus*-type strain of mice. The white cheek came from the selected strain. The gray and the colored cheek came from *blandus*.

TABLE I

TEST FOR LINKAGE BETWEEN WHITE-CHEEK, COLORED-CHEEK (Wc, wc), AND BUFF-GRAY (A^b, a)

Testcross
($A^b\ Wc/a\ wc \times a\ wc/a\ wc$)

Class	*Observed*	*Expected*
Buff, white cheek	63	50.75
Gray, white cheek	49	50.75
Buff, colored cheek	46	50.75
Gray, colored cheek	45	50.75
Total	203	203.00

ANALYSIS OF CHI-SQUARE

Source of Variation	*Degrees of Freedom*	*Chi-Square*
White cheek: colored cheek ratio	1	2.172
Buff: gray ratio	1	1.108
Linkage	1	0.833
Total	3	4.113

The testcross generation comprised 203 animals. Of these, sixty-three were buff, white cheek; forty-nine were gray, white cheek; forty-six were buff, colored cheek; and forty-five were gray, colored cheek (Table I). The buff white-cheek and the gray colored-cheek types are the parental classes. The gray white-cheek and the buff colored-cheek classes are recombinations. There is no significant deviation from the simple 1:1 ratio between recombinations and parental types that would be expected in the absence of any linkage between the genes Wc and A^b. The chi-square value is only 0.833, which is not significant. At the 1 per cent level of probability, however, the numbers are not sufficient to disprove a possible linkage having more than 37.8 per cent crossing over.

The results of this test indicate, therefore, that the genes Wc and A^b either are on different chromosomes or are very loosely linked.

GENETIC BASIS FOR THE *leucocephalus* PATTERN

The gene *Wc* accounts for only a part of the difference in coat pattern between the coast and island races of the species *polionotus* and the other members of the *maniculatus* species group. The total extension of white in these races is due to the interaction of several genes, as Sumner (1930) has already pointed out. An investigation of these other pattern genes is now in progress, and only a general statement about them is possible at this time.

White-cheek segregants in F_2 and backcross generations vary considerably in the degree of extension of white hairs over other parts of the body. Five grades of reduction of pigmented area of *Wc* mice can be recognized: (1) unmodified white cheek, which presumably represents the effect of only the gene *Wc*, (2) tail white, in which the dorsal hairs of the tail are white to their bases, (3) femoral white, in which the hairs on the inside of the thigh, in addition to the dorsal tail hairs, are pure white, (4) belly white, in which the abdominal and thoracic regions as well as the dorsal tail surface and inner thigh have white hairs, and (5) side white, in which the white area extends up onto the sides of the body. The wild type of *leucocephalus* represents at least one additional stage in reduction of the pigmented area, but this grade has not yet been obtained in the hybrids.

The highest grade of reduction of the pigmented area (side white) can be obtained from the lower grades (tail white, femoral white, belly white) by selective breeding. Conversely, the extent of the pigmented area is increased by successive backcrossing to *maniculatus*-type mice, which, because of their distant geographic origin, presumably carry few if any of the minor genes for the extension of white. Two or three backcrosses to the *maniculatus*-type animals usually result in the elimination of all completely white hairs except on the cheek and in the regions that are white in the *maniculatus* type.

The colored-cheek segregants in F_2 and backcross generations usually have a pattern of pigmentation identical with that of the parent, colored-cheek stock. Some individuals in these generations, however, have pure white hairs in the femoral region or sometimes in both the femoral and belly regions. These individuals, unlike white-cheek segregants with white femoral regions and bellies, have the dorsal surface of the tail pigmented.

From such evidence as is available, it seems probable that most of the minor pattern genes are expressed only when the gene *Wc* is present. The great variation in the extent of pigmentation of the ventral hairs in the white-cheek segregants compared with the slight variation in the colored-cheek segregants leads to this conclusion. On the other hand, the white thighs and bellies of some colored-cheek segregants indicate that some of the pattern genes reach expression in the absence of *Wc*.

The distribution of all-white hairs over the body in the house mouse is controlled by several spotting factors (see Dunn and Charles, 1937, and Dunn, 1942). My evidence, as well as that obtained by Sumner (1930), suggests that several factors also are involved in producing the *leucocephalus* type of pigmentation.

DISTRIBUTION OF WHITE-CHEEK IN NATURAL POPULATIONS OF *Peromyscus*

The distribution of the gene *Wc* in wild populations of the species *polionotus* is known only in a general way. More than three hundred wild-caught individuals of *leucocephalus* from Santa Rosa Island have been examined without the finding of any colored-cheeked animals. In addition, no colored-cheeked young appeared among the forty-two offspring of crosses between *leucocephalus* and colored-cheeked specimens of *maniculatus*. It seems likely, therefore, that the colored-cheek allele is rare in the Santa Rosa Island population.

Several stocks of the species *polionotus* that were collected by Don Hayne in western Florida are in the collection of the Laboratory. Most of the specimens available are laboratory bred, so they give no precise measure of the gene frequencies in the wild populations. However, they and such field-caught animals as are available indicate that inland from approximately the line between western Florida and Alabama the mice are colored cheeked. In the strip approximately forty miles wide between the Gulf coast and the Alabama line, both white-cheeked and colored-cheeked mice occur. On some mainland beaches the mice appear to be nearly all white cheeked; on others the populations are mixed.

The populations of the nearly white coastal beaches may be thought of as a great reservoir of white-cheek genes and of the minor color pattern genes as well. The populations of the inland, dark soils of Alabama may likewise be considered a reservoir of colored-cheek genes. Western Florida, between the coast and approximately the Alabama line is a tension zone into which are dispersed the remarkably different genotypes of the populations on each side of it. Detailed studies of the gene frequencies in the populations of this tension zone, when they can be made, will be of the highest importance to an understanding of the dynamics of raciation.

SUMMARY

The white-cheek character (*Wc*) of *Peromyscus polionotus leucocephalus* and *P. p. albifrons* is a single-unit dominant over the colored cheek (*wc*) of the species *Peromyscus maniculatus*. The genes *Wc*, *wc*, and those for buff and gray, A^b, *a*, either lie on different chromosomes or are very loosely linked.

The differences in pattern of pigmentation between the *polionotus*-type mice of the Florida coast and the inland mice of *maniculatus* type are produced by the gene *Wc* acting together with several other genes. These other genes, as yet unanalyzed, eliminate pigment from the hairs on various parts of the body.

The mice of the white beaches and islands of western Florida are mostly white cheeked, and in addition they usually carry other genes that reduce the extent of pigmented hairs on the body. The mice of the dark, inland soils of Alabama are colored cheeked. In western Florida, both white-cheeked and colored-cheeked mice occur intermingled over a strip extending approximately forty miles inland from the Gulf of Mexico.

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PLATE I

FIG. 1. White-cheek pattern of mouse derived from crosses between *Peromyscus polionotus* and *P. maniculatus.*

FIG. 2. Gray-cheek pattern of deer-mouse of *Peromyscus maniculatus blandus* stock from Alamogordo, New Mexico.

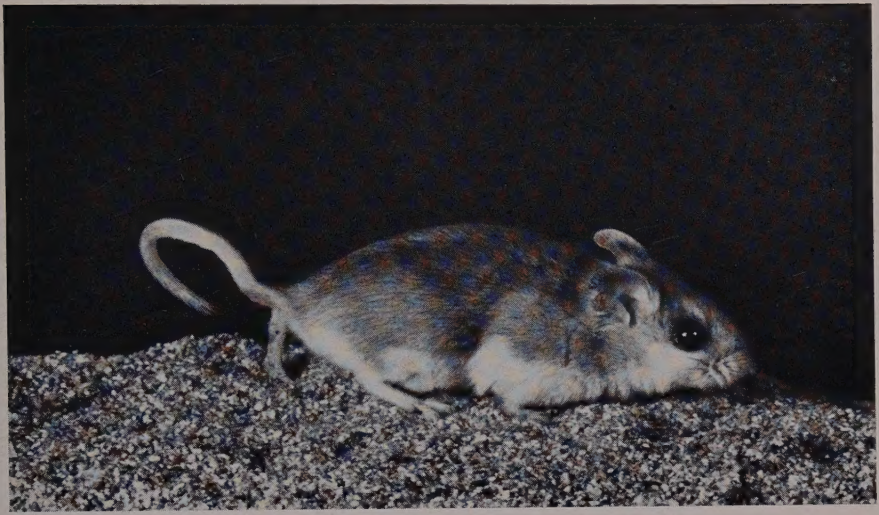

FIG. 1

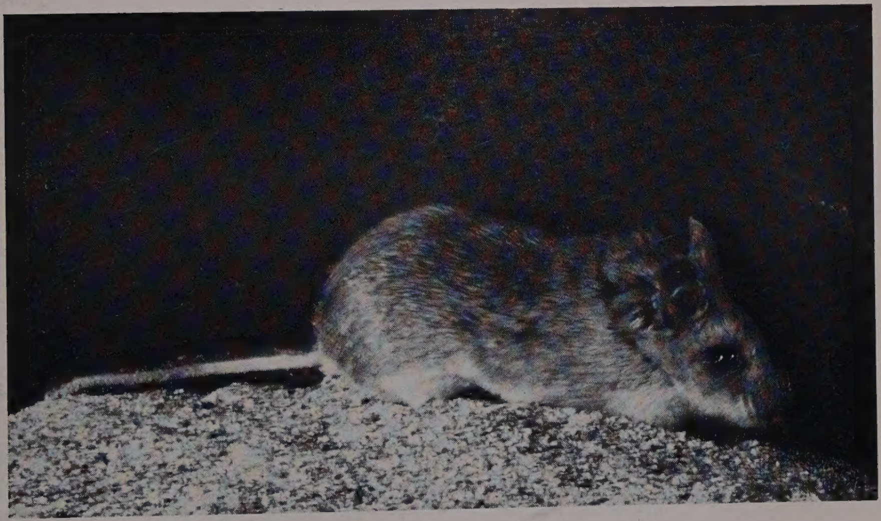

FIG. 2